III. Empirical Estimation Results

Results of the estimated nonlinear least squares model are presented in Table 5. In the table, the discount rates, r, and r_2, are constrained to be equal. In regressions in which r_1 and r_2 were not constrained to be equal, neither variable was statistically significant. In addition, an F-test indicated that the hypothesis that the two rates are the same could not be rejected at conventional significance levels.

The 1,775 observations in Table 5 represent all 1981 through 1987 vintage passenger cars owned by RTECS respondents in July of 1988 for which complete data were available. Model year **1988** new cars are considered separately from the older vehicles in the household stock because an F-test indicated that the two samples could not be pooled.

In the regression presented in column one which includes all attributes, the variables for safety--both life cycle mortality and injury rating, operating cost variables, power, reliability, and durability are all significant at the 0.05 or higher level for a one-tailed student's t-test. All variables, except cargo capacity, have the expected sign. The unanticipated sign was hypothesized to be the result of an interaction with the size categories, but this explanation proved incorrect as shown in comparative regressions.

Table 5: Nonlinear Least Squares Results
(Asymptotic standard errors in parentheses)

VARIABLE	(1)	(2)	(3)
CONSTANT	2.673	2.691	1.790
	(2.923)	(2.334)	(2.036)
QUANTITY-ADJUSTED LIFE YEARS	-1.975	-1.404	-2.511
	(1.034)	(0.697)	(1.434)
DISCOUNTED LIFE CYCLE INJURY RATING	-0.016		-0.016
	(0.007)		(0.007)
DISCOUNTED LIFE CYCLE OPERATING COSTS	0.018	0.028	0.172
	(0.009)	(0.015)	(0.010)
DISCOUNTED LIFE CYCLE OPERATING COSTS : VEHICLE WEIGHT	-0.889	-0.939	-0.932
	(0.094)	(0.073)	(0.104)
POWER	0.295	0.339	0.343
	(0.121)	(0.117)	(0.132)
CARGO CAPACITY	-0.054	-0.039	-0.057
	(0.010)	(0.009)	(0.011)
RESALE VALUE RETAINED	0.073	0.086	0.070
	(0.020)	(0.023)	(0.021)
MAINTENANCE RATING	0.031	0.030	0.031
	(0.012)	(0.013)	(0.013)
LUXURY-SPORT	0.204	0.202	0.215
	(0.012)	(0.013)	(0.012)
AUTO. TRANSMISSION	0.025	0.029	0.023
	(0.010)	(0.011)	(0.010)
TWO SEAT	-0.207	-0.067	-0.212
	(0.065)	(0.061)	(0.070)
STATION WAGON	0.128	0.085	0.152
	(0.035)	(0.034)	(0.036)
CONVERTIBLE	0.309	0.336	0.354
	(0.056)	(0.058)	(0.055)
DIESEL	-0.003	-0.003	-0.006
	(0.034)	(0.035)	(0.034)
SIZE2	-0.007	0.010	-0.003
	(0.013)	(0.013)	(0.013)
SIZE3	0.035	0.064	0.037
	(0.020)	(0.021)	(0.020)
SIZE4	0.033	0.083	0.035
	(0.031)	(0.032)	(0.031)

(Results continued on next page.)

Table 5: Nonlinear Least Squares Results (continued)

VARIABLE	(1)	(2)	(3)
AMERICAN MOTORS	-0.122	-0.064	-0.157
	(0.084)	(0.087)	('0.084)
GENERAL MOTORS	0.006	0.019	0.005
	(0.010)	(0.010)	(0.010)
CHRYSLER	0.037	0.046	0.040
	(0.013)	(0.014)	(0.013)
GERMANY	0.283	0.379	0.301
	(0.028)	(0.028)	(0.028)
JAPAN	0.188	0.230	0.191
	(0.014)	(0.014)	(0.014)
OTHER ORIGIN	0.134	0.177	0.150
	(0.028)	(0.028)	(0.027)
YEAR82	0.228	0.208	0.225
	(0.016)	(0.016)	(0.016)
YEAR83	0.379	0.338	0.376
	(0.020)	(0.020)	(0.020)
YEAR84	0.548	0.481	0.545
	(0.026)	(0.024)	(0.025)
YEAR85	0.686	0.608	0.683
	(0.033)	(0.030)	(0.031)
YEAR86	0.830	0.743	0.827
	(0.039)	(0.035)	(0.037)
YEAR87	0.951	0.844	0.948
	(0.045)	(0.040)	(0.043)
YOUNG DRIVER	-0.048	-0.051	
	(0.014)	(0.014)	
OLDER DRIVER	-0.042	-0.021	
	(0.014)	(0.011)	
LATE NIGHT	0.006	0.005	
	(0.011)	(0.010)	
ONE CAR ACCIDENT	0.005	0.004	
	(0.013)	(0.012)	
SEAT BELT	0.029	0.046	
	(0.012)	(0.012)	
ALCOHOL INVOLVEMENT	0.016	0.009	
	(0.009)	(0.008)	
MALE DRIVER	-0.014	-0.004	
	(0.015)	(0.014)	
DISCOUNT RATE	0.157	0.110	0.180
	(0.049)	(0.029)	(0.054)
LAMBDA	0.49	0.44	0.50
	(0.066)	(0.069)	(0.073)

Coefficients on dummy variables for manufacturer and nation of origin are compared against the excluded manufacturer, Ford. Cars made by Chrysler and cars made by German, Japanese, and other foreign manufacturers are valued more highly than those from Ford. The regression coefficients for American Motors and General Motors were not significant.

Dummy variables for vintage 1982 through 1987 were included with vintage 1981 excluded. The coefficients on these variables incorporate the depreciation of the vehicle and any unmeasured quality improvements. The values are all significant at the 0.01 level, and the relative magnitudes of the variables vary inversely with vehicle age indicating continuing depreciation. In some regressions, year dummies were interacted with vehicle resale value as well as entered independently. All of the interaction terms, except that for 1987, were statistically significant, but the independent discrete vintage variables were no longer significant. In those regressions, the coefficients of the interaction terms incorporated the influence of durability on price as well as depreciation and unmeasured quality improvements.

The equilibrium real discount rate is estimated at 15.7 percent. Estimating a 95 percent confidence interval about this mean rate runs from 5.9 percent to 25.5 percent. Even at the lower bound of the confidence limit, a discount rate of zero is excluded as is the prevailing real rate of return, typically estimated in the 2 to 5 percent range." These results provide strong evidence that consumer discount rates embodied in automobile holdings are higher than the social rate of discount.

Adding the 1988 inflation premium of 4.1 percent[18] to the mean estimated real discount rate implies a nominal discount rate of approximately 20 percent. This estimate is in line with the rates found in other studies, and somewhat higher than 1988 prevailing market interest rates, including the rates for automobile financing.

As expected, a higher mortality rating and a higher rating for injury (i.e. a personal injury claim is *more likely* to be filed in an accident) lower the price of the vehicle. When the injury measure is excluded from the model (Table 5, column 2), the effect of higher mortality on price is greater than when injury is included; though, the significance of the mortality rate coefficient is reduced in the regressions in Table 5.[19] In the absence of a separate measure for nonfatal injuries, the mortality measure may pick up some of the effect of nonfatal injuries. This result was first shown by Viscusi (1978) in an hedonic wage model.

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[17]Lower bound measured as 90-day Treasury Bill rate minus annual change in GNP implicit price deflator (both for 1988). Upper bound measured as AAA bond rate minus price deflator (CEA 1993).

[18]From the Statistical Abstract of the United States (U.S. DOC 1992).

[19]Though the coefficient on mortality in regression two is less than the coefficient in regression one, the change in lambda accounts for the greater total effect.

Several of the driver behavior variables are statistically significant. The proportion of younger drivers, the proportion of older drivers, and the proportion wearing seat belts are all significant at the 0.05 level using a two-tailed student's t-test. When the nonfatal injury measure is included, the alcohol involvement variable is significant at the 0.10 level. Somewhat surprisingly, male drivers was not statistically significant. Along with driver age, and alcohol use, this is often considered the most important factor in accident rates, but the lack of statistical significance may indicate that they have a lower association with particular vehicle models than generally assumed. Interpretation of the signs of these variables is difficult because the influences of some behavioral factors may be opposed. For example, people who wear their seat belt may be more safety conscious, leading them to own safer cars. On the other hand, owning a safe car may lead to more reckless driving as hypothesized by Peltzman (1975).

The influence of the behavioral variables is opposite in direction to that found by Atkinson and Halvorsen. Their formulation included young drivers, male drivers, alcohol involvement and seat belt usage. None of the behavioral characteristics proved to be significant, but on net, including the four controls diminished the effect of mortality on price by 26 percent.

The dollar value of consumers' marginal willingness-to-pay for changes in the annual cost of driving can be calculated from the transformation coefficients of the annual operating cost variables'. For each observation, the change in vehicle price given a unit change in annual operating costs is calculated as follows,

$$\frac{\partial \text{vehicle price}}{\partial \text{annual cost}} = \left[\beta_1 * \text{annual cost}^{\lambda-1} + \beta_2 * \frac{\text{annual cost}}{\text{weight}}^{\lambda-1} * \frac{1}{\text{weight}}\right] * \text{price},$$

where β_1 and β_2 are the estimated Box-Cox transformation coefficients of annual operating costs, and the ratio of annual operating cost to vehicle weight, respectively, and as before, λ is the estimated Box-Cox transformation coefficient for the independent variables. The right hand side is post-multiplied by vehicle price because the model was estimated using the log of vehicle price as the dependent variable. The mean value of the expression is calculated by evaluating the expression for each observation and then calculating the mean weighted by the RTECS population sampling weights.

This value, the change in price for a change in annual cost, represents the present value as reflected in the market value of the vehicle, of a one dollar change in fuel costs over the life cycle of the vehicle, the present value of unit operating costs (PVOC). Because PVOC is a present value, it is composed of three entangled unknowns, the discount rate, expected vehicle life, and the extent of capitalization as in the expression,

$$PVOC = \gamma\,[1 + e^{-r} + e^{-2r} + \ldots + e^{-Tr}],$$

where γ is the capitalization rate, T is the expected vehicle life, and r is the discount rate. The discount rate is the rate at which consumers trade between current and future savings in fuel expenditures. The expected vehicle life will vary depending on the age and model of each vehicle.

The capitalization rate refers to the rate at which the marketplace incorporates life cycle fuel costs into market prices of vehicles. If there is perfect capitalization, i.e. a one-to-one correspondence between changes in the discounted value of life cycle operating costs and vehicle price, then the capitalization rate is one. If however, there is no relationship between life cycle fuel expenditures and vehicle price, the capitalization rate would be zero.

Based on the regression estimates in Table 5 for the sample of pre-1988 vehicles in household holdings, the estimated mean willingness-to-pay for a one dollar change in life cycle operating costs, is $ 0.39.

The mean willingness-to-pay values are surprisingly low. Possible explanations for such low values include improper model specification and the possibility that automobile consumers act irrationally, but the results are not necessarily implausible given the specifics of the automobile market. Because vehicle choices in the marketplace are constrained by the inherent discreteness of the good in question, automobiles, some consumers may make choices that appear irrational in terms of fuel economy tradeoffs, but are instead a result of the consumers' selection criteria confronting the realities of the marketplace. If a consumer ranks fuel economy low on the list of selection criteria, vehicle selection within the criteria-constrained choice set may not reflect fuel economy tradeoffs. This is demonstrated by a number of observations in the data set for which the value of the willingness-to-pay for operating cost savings is negative.

Both the low capitalization rate and the high discount rate could be the result of the application of the estimation model. It is assumed in these estimates, that a vehicle lasts thirteen years and then has no scrap value. This assumption is based on the median time to scrap for all vehicles on the road. The median time that car buyers expect to keep their new cars is only 5.5 years (MVMA 1992). After this period, well over 90 percent of vehicles are still on the road. Upwardly biased rates could occur if a consumer bases a vehicle ownership decision on a short time frame, but the discount rate is calculated for a longer time frame. The computed discount rate may appear higher than the rate underlying the ownership decision.

Two sources of measurement error may have been introduced by data on the expected lives of vehicles and vehicle owners. The thirteen year expected vehicle life ignores variability among different makes and models. However, other variables like manufacturer and durability may act as controls for variability across vehicles minimizing any errors associated with measurement of expected vehicle life.

Discounted remaining life years are calculated based on the characteristics of the household head as reported in the Department of Energy RTECS survey data. If the household head is not the purchaser/holder of a vehicle reported for the household, then an error may be introduced.

While modelling considerations may have affected the estimated discount rate, the similarity between the rate estimated here and those estimated in numerous other studies serves as a strong indication that the estimated rate may reasonably underlie household automobile holdings.

Based on the nonlinear least squares estimates in Table 5, column 1, the estimated mean value of a statistical life as reflected in automobile holdings in a life cycle context is \$2.48 million, with extreme values of \$20.1 million and \$336,000. The mean value of a life year is approximately \$101,000 with extreme values of \$1.4 million and just over \$8,000.[20]

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[20]All values in 1988 dollars.

In column two of Table 5, results are presented for the model excluding the injury variable. The mean statistical value of life in this case is over $2.8 million--16 percent higher--indicating that excluding a separate measurement for nonfatal injuries causes the fatality valuation to reflect the value of nonfatal injuries.

The third regression result in Table 5 demonstrates the importance of including controls for the driver characteristics in fatal accidents. The mortality risk measure used in the model does not represent a pure measure of automobile-specific risk because driver characteristics are not excised from the rates. Therefore, selected characteristics of drivers in fatal accidents are included in the model as control variables. As defined in section II, these controls measure the proportion of fatal accidents occurring in each make/model/year vehicle that reflect the characteristic in question. The first column in Table 5 indicates that the proportion of drivers who are young, those who are older, and those wearing seat belts were all statistically significant at the 0.05 level, and alcohol involvement was significant at the 0.10 level. Excluding these control variables as in the results presented in column 3 leads to a mean value of a statistical life in the life cycle context of $2.76 million, more than 11 percent greater than when the controls are included.

Table 6 presents mean life and life year values for different demographic characteristics of the RTECS sample population. These values demonstrate how willingness-to-pay to avoid risk varies across individuals. Because the hedonic price locus is nonlinear, implicit prices are locally applicable for only those individuals sorted to that point on the locus. The values in Table 6 were calculated by estimating the implicit value of a statistical life (and life year) for each observation in the sample. Those values were then averaged over individuals based on their demographic characteristics.

The first row in the table clearly shows the expected income normality result that the statistical value of life varies positively with income. Individuals in the highest income quartile in the sample revealed a mean statistical life value of $2.99 million compared to $2.15 million for the lowest income quartile. No clear pattern can be discerned for the value of a statistical life year across income groups.

A distinctly different pattern emerges from analysis of the valuations with respect to age categories. The second row of Table 6 shows mean valuations for different life expectancy quartiles. The lowest quartile reflects the oldest segment of

Table 6: Estimated Mean Valuations for a Statistical Life and Life Year For Demographic Categories ($1000 1988)*

INDIVIDUAL DEMOGRAPHIC CHARACTERISTICS

VARIABLE	HIGHEST QUARTILE	2nd QUARTILE	3rd QUARTILE	LOWEST QUARTILE
INCOME				
LIFE VALUE	$ 2,986	$ 2,435	$ 2,382	$ 2,147
LIFE YEAR	115	89	97	103
LIFE EXPECTANCY				
LIFE VALUE	2,251	2,450	2,520	2,702
LIFE YEAR	46	64	94	195
MEAN LIFE EXPECTANCY+	50 years	38 years.	27 years	15 years

INDIVIDUAL DEMOGRAPHIC CHARACTERISTICS

GENDER	
MALE	
LIFE VALUE	$ 2,549
LIFE YEAR	114
FEMALE	
LIFE VALUE	2,397
LIFE YEAR	84
RACE	
WHITE	
LIFE VALUE	2,492
LIFE YEAR	101
BLACK	
LIFE VALUE	2,374
LIFE YEAR	100

VEHICLE CHARACTERISTICS

	HIGHEST QUARTILE	2nd QUARTILE	3rd QUARTILE	LOWEST QUARTILE
MORTALITY RISK				
LIFE VALUE	$ 1,454	$ 1,946	$ 2,583	$ 3,917
LIFE YEAR	48	78	110	165
VEHICLE SIZE**				
LIFE VALUE	1,671	1,971	2,588	4,048
LIFE YEAR	58	72	101	195

* Results from column 1, Table 5.

\+ Based on age, race, and gender.

** Means for vehicle size categories, smallest to largest.

the RTECS sample population, those with the shortest life expectancy. Their mean value of a statistical life equals $2.70 million. The youngest quartile, those with the longest life expectancy demonstrate a 17 percent lower valuation equal to $2.25 million. The difference is likely to be due to a wealth effect as each age quartile is likely to be wealthier than the next youngest quartile.[21] A wealth or income effect, however, cannot account for the differences in the valuation of a statistical life year across the age categories. From the first (youngest) to the fourth (oldest) quartiles, the value of a life year rises by over four times, from $46,000 to $195,000. Between these two groups, the mean life expectancy differs by thirty-five years. The numbers become even more differentiated at the extremes of the population. For the youngest 10 percent of the population, a statistical life year is valued at $40,000, while for the oldest 10 percent a statistical life year is valued at $236,000.

These results indicate that while the value of a statistical life changes across age categories, probably due to income differences between the groups, the value of a life year changes substantially. For the oldest segment of the marketplace, a life year is more precious than that for the

[21]Each successive age quartile has a higher income than the previous quartile except for the oldest quartile which has the lowest income of all groups. This pattern is probably due to retirements in the eldest segment. Nevertheless, the eldest segment is likely to be substantially wealthier than the younger segments.

younger population segments. The actual valuations are probably even more extreme than those depicted here, as these values are average values. A measure of a marginal life year may be even more diverse.

Other characteristics for which is was possible to make demographic distinctions in statistical life values include gender and race. Men revealed a statistically significant (0.10 level) greater mean willingness-to-pay for a statistical life than women of 6 percent, but the value of a statistical life year for men was 37 percent greater than for women. This unusual result may be explained because the average life expectancy of women was greater than the average life expectancy of men by over six years.

No statistically significant differences in the value of a statistical life or life year were detected between blacks and whites who responded to the RTECS survey. Blacks comprised six and one-half percent of the observations used in the regressions, somewhat lower than the proportion of blacks in the general population.

The characteristics of the auto held by an individual also reflect differences in valuations. Naturally, valuations are negatively related to safety, individuals choosing safer cars, those with a lower mortality risk, will demonstrate a higher willingness-to-pay for the additional safety. The difference in the value of a statistical life between the lowest and highest risk quartile is more than two times. Vehicle size categories appear to be good proxies for the risk quartiles as the means of all the risk quartiles except for the smallest cars are not statistically different from the means of the valuations of the size categories.

IV. <u>Policy Implications</u>

Policies designed to curb consumers' demand for gasoline can take two approaches. One is to create incentives to reduce driving. The second is to change the mix of vehicles held by consumers." The policies presented in section I address the second source of potential savings, the vehicle mix (though policies like the gas tax may also affect driving demand). The results presented above indicate that policies which attempt to address automobile fleet fuel economy improvements through operating costs may be less successful than programs which address vehicle price because consumers overemphasize the up-front price relative to life cycle operating costs.

One underlying explanation for the lack of responsiveness of vehicle price with respect to operating costs is that consumers discount future costs at **a** high rate. If capital market are efficient, a utility-maximizing car owner will discount the future flow of operating expenditures at the prevailing interest rate. Any other discounting pattern would lower utility. If the consumer's rate is higher than the prevailing interest rate, the consumer could be made better off by borrowing at the going rate, investing in **a** higher priced, more fuel efficient vehicle, all else equal, and repaying the

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[22]Consumer car holdings and driving patterns are closely linked. For instance, new cars are driven more in their first year than in subsequent years. As the vehicle fleet becomes more fuel efficient, there is an incentive to drive more because vehicle operating costs per mile are lower. This "rebound effect" has been the focus of substantial study, but in a comprehensive review, Greene (1992) concludes that the effect is small, and occurs primarily in the short-run.

loan from the flow of future operating costs savings. With a lower discount rate than the market rate, the opposite policy would be utility-improving.

An analogous decision process occurs in the market for risk. Consumers may borrow in capital markets to alter the risk profile of their automobiles. If the consumer's discount rate for risk exceeds the market interest rate, then a utility maximizer should invest in additional safety. Knowing the rates at which consumers' implicitly discount their future expenditure and risk flows is a key element for evaluating public policies designed to alter consumer behavior.

These results indicate that consumers could in many cases be made better off by owning a more expensive car with a lower mortality risk or a higher fuel economy where the future flow of operating cost or safety savings could be used to finance the higher initial cost. An alternative explanation for high discount rates is that consumers reasonably incorporate premia for illiquidity, risk, and uncertainty in their implicit discounting behavior.[23] Even if such individually rational considerations underlie high discount rates, individual behavior remains at odds with the social optimum.

The observed discount rate and the low observed capitalization rate have important implications for the effectiveness of different policy approaches. The gasoline

[23]Alternative individually rational explanations for high individual discount rates are discussed in detail in Dreyfus (1993).

tax, which creates an incentive to own more fuel efficient vehicles by raising operating costs, faces substantial obstacles for altering the fuel economy mix of vehicle holdings.

The ineffectiveness of operating cost approaches is exaggerated by the response pattern observed across the size segments of the automobile market. Holders of the smallest, most fuel efficient cars are the most likely to respond to changes in operating costs. But for any given incremental change. in fuel efficiency, these vehicles provide the least reduction in total gasoline consumption.

Fuel economy standards and policies that address vehicle price such as feebates and the gas guzzler tax may be more effective than gasoline taxes for changing the fuel economy mix over the long-run. These proposals are all limited in their short-run effectiveness, however, because the effects of the policies filter through the vehicle fleet only as the existing fleet is replaced with new vehicles. Automobile bounty programs could be used as a near-term supplement to fuel economy standards or pricing policies to speed the replacement rate of the most fuel inefficient vehicles.

An estimate of the value of a statistical life is an important component of the evaluation of policies designed to conserve fuel in automobiles. The trade-off between safety and fuel economy embodied in each automobile has long been recognized. This issue has now become one of the central focuses in consideration of extension of the Corporate Average Fuel Economy (CAFE) requirements. But in addition, the safety-fuel economy issue should be considered in the evaluation of any automotive fuel economy conservation proposal.

In one study of the CAFE requirements as they have been implemented to date, Crandall and Graham (1989) evaluated the safety implications of modifications in the fuel economy performance of the new vehicle fleet. Based on a review of the relationship between mortality rates and vehicle weight, they projected that the mortality rate of the 1989 model year vehicle fleet would be from 14 to 27 percent higher than in the absence of the CAFE requirements.

Such safety implications are a crucial component for evaluating fuel economy proposals in a benefit-cost framework. In such a framework, the fuel savings of each policy and all other associated benefits--like savings from reduced air pollution and national security savings--should be compared against the costs. One of those costs is the safety consequence, both fatal and nonfatal, of each policy.

Classifying the number of cases of fatal and nonfatal injury is the first step to evaluating these costs. The second step is placing an economic value on each statistical case. In this context, the most appropriate measure of a fatal or nonfatal injury is the consumers' willingness-to-pay to accept (or avoid) an injury as expressed in the automobile marketplace. Based on this research, the best estimate of the mean value of consumer willingness-to-pay for a fatal injury is approximately $2.48 million. Using demographic breakdowns, willingness-to-pay can be more accurately specified based upon the characteristics of the individuals bearing the costs of the policies.

The estimates in this research of the value of a statistical life and of the consumer discount rate embodied in household automobile holdings are critical pieces of information for the broader evaluation of policies addressing automotive fuel consumption. Decisions made in the public arena which have broad implications for the health and safety of the general public as well as the more directly observable pocketbook implications should meet a test of positive net social benefit. These estimates fill an essential niche in the public information set necessary to conduct that benefit test.

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APPENDIX

Data Set Description and Data Sources

The Residential Transportation Energy Consumption Survey (RTECS) was conducted by the Energy Information Administration of the U.S. Department of Transportation in 1988. The sample contained 2,986 households randomly selected from the U.S. with over-sampling of low income households and sampling targeted to include 50 percent high mileage households and 50 percent low mileage households. Each household had been interviewed in 1987 as part of an larger survey, the Residential Energy Consumption Survey (RECS). In the RECS, data on the household vehicle stock and household characteristics were collected. Each household was contacted four additional times during 1988 and 1989 for RTECS. The beginning-of-year contact was conducted by telephone (with a mail supplement for households without telephone access), collecting information on the updated vehicle stock, vehicle characteristics, fuel type and grade, and odometer readings. The mid-year contact was conducted by mail with a telephone follow-up. Mid-year contact was designed to update the vehicle stock. The end-of-year contact occurred in early 1989. End-of-year contact was again conducted by telephone, and contained questions similar to those from the beginning-of-year contact with emphasis on updating the vehicle stock for acquisitions and dispositions during the year. Prior to the first and final contact, each household was sent an odometer reading card to be used as a reference during the subsequent telephone contact.

Vehicle Holdings: Vehicle holdings for the 2,986 households were collected for calendar year **1988.** All cars bought and sold were recorded during this period. In the empirical estimates vehicle holdings have been updated **to** include only those vehicles owned in July of **1988.** On that date, 11.3 percent of all households owned no vehicles, while 30.8 percent owned one car, 39.5 percent of households owned two cars, and 18.5 percent owned three or more. The 6,452 vehicles owned by respondents ranged in age from a 1939 oldsmobile to new 1989 model year cars. Vehicles were identified as standard passenger cars, two-seat cars, station wagons, large vans, mini vans, pickup trucks, jeep-type vehicles, and other. Over 70 percent of the vehicles were cars and station wagons, 4.5 percent were vans, and 17.1 percent pickup trucks.

Engine Characteristics: Detailed **information** on the engine of each vehicle was collected in RTECS, including the number of engine cylinders, and measures of engine displacement. In most cases, these variables **were collected** by decoding the vehicle identification number (VIN), a **fifteen** digit code assigned by the manufacturer and displayed on a metal plate, usually on the inside of a door panel. The VIN contains highly specific information about the type of car and its characteristics, such as specific engine type and emissions controls installed. The survey was able to collect a valid VIN for approximately 77 percent of the vehicles. For those for which a VIN was not available, engine characteristics (and other variables) were collected by questionnaire. In some cases, imputed data were included in the data set. The reliability of each vehicle's engine characteristics is especially important because other supplemental data collected by the author relied on the reported engine characteristics.

Vehicle Make, Model & Vintage: The make, model and vintage (i.e. model year) of each vehicle was reported in RTECS based on VIN decoding. In those cases where VINs were unavailable, questionnaire responses were used. Accurate reporting of vehicle make, model and vintage is important for the collection of supplemental data by the author.

Adjusted Mileage Rating: The EPA composite miles per gallon (MPG) rating was collected based on VIN numbers or reported make/model, and was adjusted in a sequential procedure to reflect actual on-road fuel economy of each vehicle. Based on the VIN or survey information for each vehicle, the EPA test MPG for city and highway use were assigned. These values were adjusted by the city and highway shortfall factors accounting for the difference between the EPA test MPG, which is conducted on a dynamometer, and actual on-road MPG. The shortfall-adjusted on-road city and highway MPG estimates were then weighted by 0.55 and 0.45, respectively, for the shortfall-adjusted on-road composite MPG estimate. In the final step, the ratings were adjusted using a regression model for in-use MPG based on the individual circumstances of the vehicle and owner. This adjustment reflects such characteristics as urban versus rural driving pattern, population density, weather patterns, and road conditions. In addition, the in-use adjustments incorporate differences in city and highway driving of the individual vehicle based on the odometer readings for that vehicle (e.g. high mileage vehicles are assumed to log more highway miles than low mileage vehicles). These adjusted in-use MPG values are used in the empirical estimates.

Fuel Price: The fuel price for each vehicle was assigned by RTECS based on Bureau of Labor Statistics retail values for the region, type of gasoline consumed, and type of service reported for each vehicle. A more differentiated value for fuel price would be desirable, but the inability to identify households more specifically than by their census division (to insure respondent anonymity) prevents collecting more detailed data.

Transmission Type: The type of transmission, either manual or automatic, was reported by RTECS based on reported VINs and respondent questionnaires.

Vehicle Price: Vehicle prices were collected by the author from three different sources depending upon the vintage of each vehicle. Model year 1988 vehicle prices are based on manufacturers' suggested retail price as reported in standard industry sources, either Ward's Automotive Yearbook or Automotive News Market Data Book. These prices were adjusted to incorporate the engine size and transmission type reported in RTECS. Prices were also normalized by assuming that every vehicle was equipped with an air conditioner, power steering, power brakes, and an am/fm radio when those options were available from the manufacturer. When a number of different models were offered by manufacturers (e.g. the Toyota Celica GT or ST), but the RTECS report did not specifically identify the model, the lower priced model was assumed. Similarly, when body style (such as sedan or liftback) was unknown, the price for a sedan was used. In most cases, it was possible to determine from the RTECS make/model reports whether a vehicle was a two-door or four-door. In those cases were this information was not available, the number of doors was assigned based on a random draw, and the price assigned accordingly. Where applicable, the gas guzzler tax was included in the vehicle price, but other taxes, registration, and licenses were excluded. Prices for 1981 through 1987 vintage vehicles were collected from the 1988 end of year issue of the Automobile Red Book of official used car valuations. Price adjustments similar to those for new cars were made to account for available options, two and four-door vehicles, and low priced models. Specific values were assigned depending on the engine configuration of each vehicle and the transmission type.

Resale Value Retained: The percent of original resale value retained was calculated based on the original model year new car sales value and the used car market value as of end of year 1988. Both values were drawn from the Automobile Red Book of used car values. No values were entered for 1988 model year vehicles. In many cases, the Red Book information identifying the specific make/model was more detailed than the RTECS information identifying the vehicle make/model. For example, Red Book may list different values for several different engine configurations where RTECS listed only the number of cylinders and liters. To minimize mismeasurement of the retained resale value, the value assigned each RTECS make/model was the average of the retained resale values of all vehicles listed in the Red Book for that make/model.

Horsepower: Vehicle horsepower was assigned by applying industry horsepower ratings found in standard trade publications to the engine characteristics reported in RTECS. In some cases, the industry sources did not cite horsepower for the reported engine configuration. Horsepower was assigned based on a same make/model vehicle from a previous year or from a same year, similar make/model vehicle with the engine configuration in question.

Vehicle length, width, and weight: These values were drawn from industry trade publications based on the RTECS reported make/model/vintage, the reported engine characteristics, and the number of doors in each vehicle. In some cases, weight estimates were not available for vehicles with optional engine configurations. Incremental weight adjustments were incorporated based on similar vehicles or the vehicle weight was left unadjusted for that vehicle, usually resulting in an underestimate of true vehicle weight by less than five percent.

Interior shoulder room *and vehicle* cargo space: The values were drawn from Consumer Reports Annual Car Buyers Issue, published annually in April. Shoulder room is the sum of front and rear shoulder room in inches for standard vehicles and front shoulder room, alone, for two seat vehicles. Cargo space is measured in cubic feet of volume. For station wagons, cargo space data was drawn from the Gas Milease Guide published annually by the U.S. Department of Energy. In cases in which is was unclear from RTECS whether a vehicle was a sedan or a hatchback, the cargo volume for the sedan was included.

Safety Rating: The vehicle safety rating is drawn from the annual Insurance Iniurv Report of the Highway Loss Data Institute. The specific value represents the relative frequency of insurance claims for personal injury for that vehicle normalized by the gross insurance exposure for the vehicle. The ratings are scaled in relative terms with **100** being the claim frequency for all vehicles combined. A relative claim frequency rating of 50 implies 50 percent fewer claims for that vehicle, while a relative claim frequency rating of **150** implies 50 percent more claims than that for all cars combined. Ratings usually cover three model'years except in cases where the model was redesigned during the three year interval. The ratings were adjusted to reflect the ratio of young drivers to older drivers. In most cases, separate values were reported for two-door and four-door models and station wagons.

Vehicle Mortality Risk: Vehicle mortality risk was computed based on data from the Fatal Accident Reporting System maintained by the U.S. Department of Transportation (DOT). The DOT provided records for every fatality occurring in a passenger'car or truck in 1989. The total number of fatalities occurring in each make/model/year vehicle type was calculated from these records. Separate values were calculated for standard cars, two seat models, station wagons, and convertibles. The mortality rate was calculated by dividing the number of fatalities associated with each make/model/year vehicle by the number of vehicles of that type expected to be on the road in 1989. Vehicle sales data for each make/model/year vehicle were collected from standard industry sources, primarily Wards Automotive Yearbook. Sales were collected separately for standard cars, station wagons, two seat vehicles, and convertibles. The sales of some import vehicles could only be collected by calendar year rather than by vehicle model year, potentially leading to inaccurate sales data if the sales for that make/model/year differed substantially from the sales in the prior year. A final adjustment was made to account for the proportion of cars from each model year actually on the road in 1989. Data from MVMA Facts and Fisures were used to determine the number of vehicles from each model year retired between